Thermophysical and topographic analyses of conical mounds in northern Terra Sirenum, Mars: Implications for their origins

*逸見 良道[1]、宮本 英昭[1]
*Ryodo Hemmi[1], Hideaki Miyamoto[1]

1. 東京大学大学院工学系研究科システム創成学専攻
1. Department of Systems Innovation, School of Engineering, The University of Tokyo

There are no planetary bodies other than the Earth, where presence of active mud volcanoes have been conclusively confirmed. However, considering possible conditions on planetary surfaces billions of years ago, ancient Mars may also have formed fields of mud volcanoes on its surface, as suggested by previous studies [e.g., *Oehler and Allen*, 2010; *Skinner and Tanaka*, 2007; *Pondrelli et al.*, 2011]. Despite their great significance to the evolution of Mars surface, discerning possible mud volcanoes and the other analogous features is still challenging, and the detailed formational mechanism of mud volcanoes, even terrestrial ones [*Kopf*, 2002], remains uncertain, partly due to paucity of studies on the quantitative characterization of their complex spectral signatures and a variety of their geometries and dynamical behaviors.

We here conducted thermophysical analysis on conical mounds inside an elongated basin-like structure (centered at 203.2°E, 26.7°S; between Bernard and Cross craters) in northern Terra Sirenum on Martian southern highlands. We utilized 100 m/pixel thermophysical dataset, Thermal Emission Imaging System (THEMIS) thermal inertia map [*Christensen et al.*, 2013; *Fergason et al.*, 2006], generated from nighttime infrared images acquired by the THEMIS instrument onboard Mars Odyssey spacecraft [*Christensen et al.*, 2004]. Thermal inertia (units of J $m^{-2}s^{-0.5}K^{-1}$, referred to as thermal inertia unit, tiu), is defined as the square root of the product of thermal conductivity, bulk density and the specific heat of surface materials and represents the ability for the materials to store and radiate heat, which is strongly controlled by particle size. As a result, locations of relatively low thermal inertia values well correspond to the spatial distribution of the circular mounds identified in the Mars Reconnaissance Orbiter (MRO) ConTeXt (CTX) camera images with ~6 m/pixel spatial resolution [*Malin et al.*, 2007], and the differences in thermal inertia between the mounds and the surrounding terrain are up to ~400 tiu. This indicates that the surface of the mounds consists of finer particles rather than the coarser ones forming the adjacent plains, which implies the finer grains (silt to fine sands) have covered at least surficial part of the mounds.

Moreover, we measured the slope angles of targeted conical mounds by generating four high-resolution digital elevation models (1 or 2 m/post; expected vertical accuracies of tens of centimeters [*Kirk et al.*, 2008]) from stereo pairs of MRO's High Resolution Imaging Science Experiment (HiRISE) images [*McEwen et al.*, 2007]. Their mean slope angles of the fifty mounds ranges from 5.4±2.0 to 19.8±11.0 degrees, mostly lower than the angle of repose. More importantly, the cross-sectional profiles of some mounds show upward-convex geometry, which is consistent with deformation of plastic materials with finite yield stress, rather than ballistic deposition and/or mass movement. Therefore, we applied a simple model of a mound-shaped Bigham fluid [*Blake*, 1990; *Hulme*, 1974; *Moore et al.*, 1978] to the morphometric parameters measured from the mounds, to roughly estimate yield strengths of the mound-forming materials at the halt of the horizontal expansion. The yield strength estimates resulted from this modeling are on the order of 10^3–10^4 [Pa] which are comparable values to those of mud samples of terrestrial mud volcanoes and basaltic magmas from active volcanoes [*Tran et al.*, 2015]. Combined with constituents suggestive of finer grains and their morphologies of flow-like peripheries, we assume these estimates can be explained most simply by the eruption and subsequent flows of muddy materials, while volcanic cones covered with fine particles cannot be completely precluded. With either origin of the

mounds, they exist in spatial relation to older tectonic features (e.g., impact craters, grabens) on a regional scale, implying the interaction between confined groundwater and fault systems. Hyperspectral and in-situ observations of both the Martian mounds and terrestrial mud volcanoes, are necessary not only for identifying the origin of the mounds but for better understanding of paleohydrology and resource assessment of Martian subsurface on a global scale.

キーワード：火星、リモートセンシング、泥火山
Keywords: Mars, Remote sensing, Mud volcanism

